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Computing readiness-based sparing

CNA is developing a new readiness-based sparing (RBS) methodology to determine spare parts buys for deployed aviation units. With RBS, the expected readiness of the aircraft units is the criterion that determines the mix of parts to buy. Given a fixed dollar amount, one buys the collection of parts that maximizes the expected readiness. Or conversely, given a readiness goal, one buys the lowest-cost collection of parts to achieve that goal.

The shortcoming with existing RBS models lies in how they calculate expected readiness for a particular collection of spares. To simplify calculations, existing RBS models make one or more assumptions. For example, they may assume that, when an aircraft becomes non-mission-capable (NMC), only a single component failure is responsible. Therefore, the repair time of the aircraft is determined by the repair time of a single component. This same assumption is also applied to the sub-component failures of a failed higher-level component. Previous analysis of aircraft and part failure data has shown that this assumption is almost never valid.

The new RBS model, called Multi-Indenture, Multi-Echelon Readiness-Based Sparing (MIMERBS), allows for the failure of any subset of components or sub-components. Given a sparing policy, the model computes the expected down time of a failed aircraft, which is easily converted to aircraft availability, in an analytically rigorous manner. In particular, the probability of waiting for a needed part and the expected waiting time given the part is not on-hand are computed using a mathematical technique based on a birth-death process. Overall repair times are computed by explicitly integrating the repair time distributions for all of the sub-components. The disadvantage of this approach—one that may have precluded its use in the past—is that the extensive computations needed to find an optimal sparing policy require a super-computer to complete them in reasonable time.

Because the Navy wasn't going to buy a super-computer to determine parts buys, we decided to build our own. We built a virtual super-computer by exploiting the unused computing power latent in an existing network of office desktop computers. We implemented the MIMERBS model in such a way that it parcels out portions of the computation to a collection of PCs connected by a standard ethernet. Thus, the computations proceed in parallel, and the computational horsepower is limited only by the number of PCs available on the network. All computations occur in the background, so the PCs continue to support ordinary office tasks (e.g., word processing, spreadsheet manipulation, web browsing) while participating in the virtual super-computer. The virtual super-computer is robust and fault-tolerant: if any PC crashes, is rebooted or turned off, the computations in progress on that PC are automatically redistributed to other PCs. Further, the virtual super-computer will detect when a PC is booted and automatically initiate computations on that PC.

Currently we are experimenting with a prototype virtual super-computer comprising 30 PCs. This prototype is being used to test the concepts and experiment with the various mathematical algorithms that can be used to perform the optimization. This 30-PC prototype has already demonstrated sustained performance of 7 Giga-FLOPS (7×10^9 floating point operations per second)—performance equivalent to an eight-processor Cray C90 or a four-processor

Cray T94. Current experiments indicate that these distributed processing techniques will work well with up to several hundred PCs, potentially achieving performance approaching 100 GigaFLOPS. If such performance is achieved, the resulting virtual super-computer would rank among the 100 fastest super-computers in the world.
(Dr. Ron Nickel, (703) 824-2463)

Seasonal variation in fleet manning

Undermanning in the fleet has been a major concern in the Navy over the past year. Recent recruiting and retention difficulties account for only part of the concern. Another factor is a structural problem in the personnel system that produces a seasonal variation in fleet manning. Fleet manning is relatively high from December to May and relatively low the rest of the year—a pattern that has persisted for at least 15 years. The cause of the variation is the combination of a surge in accessions during the summer and enlistment contracts that end in the same season several years later. Because the average sailor takes six months to reach the fleet after joining the Navy, fleet losses peak in the summer months; fleet gains don't peak until the winter months.

To address the problem, we examined modifications to contract lengths that would better distribute fleet gains and losses. We considered modifications to contract length both across-the-board and for specific occupations. With the former, the Navy would tie contract obligation to the completion of training instead of upon entry to the Navy; with the latter, contract lengths would change only for those who enter the fleet directly from boot camp without training. Our simulations presented policymakers with trade-offs between solving the aggregate problem (i.e., minimizing overall seasonal variation) and solving the problem for selected occupations. We are currently investigating the implications and cost of a third option: level-loading recruits into the Navy.
(Dr. Henry Griffis, (703) 824-2208)

Increasing enlistment contract lengths

By design, the Marine Corps is a young force, with almost 70 percent of its enlisted personnel in the first term of service. About 35,000 new Marines enter the enlisted force annually, 80 percent of whom sign four-year contracts. Although the Marine Corps has had more recruiting success than the other Services in recent years, a difficult recruiting market is putting increased stress on recruiting resources. The Marine Corps asked CNA to investigate the implications of increasing the length of contracts.

We examined the effect of increased contract lengths on accession requirements and the percentage of the first-term force in full-duty assignments. We found that longer contracts would benefit the force in two ways. First, longer contracts would reduce the number of new recruits needed. Because fewer personnel would leave the Service every year, fewer would be needed to replace those leaving. (Of course, recruiting new recruits with longer contracts would likely be more difficult and could increase the cost of recruiting.) Second, longer contracts would increase the fraction of the first-term force available for fleet assignment. For example, we estimate that increasing 10 percent of the contracts from four years to five would increase fleet manning by about 500 personnel—approximately the number of first-term personnel in an infantry battalion.
(Dr. Aline Quester, (703) 824-2728)

Military relations between U.S. and PRC

Under the auspices of Project Asia, CNA examined the military relations between the U.S. and the PRC. The study was unique in that it attempted to understand the relations from a Chinese perspective. Among the study's findings, three stand out as having important policy implications:

- The PLA's engagement with the U.S. defense establishment is an extension of Beijing's national strategy and policies towards the

United States. The decision to engage the U.S. armed forces, the parameters of that engagement, and the timing of key military engagement events are subject to the decisions of China's political leadership. The PLA as an institution does not have the authority to make these types of basic decisions on its own. Although this may seem obvious given how our own system in the United States operates, this finding counters popular images and characterizations of the PLA as an omnipotent institution autonomous of civilian authority.

- The most important objective that the PLA pursues in military relations with the U.S. is the advancement of Beijing's strategic agenda vis-a-vis Washington. For the Chinese, the line between the political and the military is amorphous. Political relations and military relations are merely different means to the same end. This explains in part why the PLA will not be more transparent with U.S. uniformed and civilian defense officials. The PLA does not see any point in being more transparent at the operational level until it receives more transparency from the U.S. at the strategic level. For example, the PLA (and the Chinese political leadership) wants explicit reassurance that the U.S.-Japan Revised Guidelines for Defense Cooperation do not include the defense of Taiwan and that the U.S. will commit to curtailing and eventually ending arms sales to Taiwan.
- The way in which the Chinese prefer to approach the phasing of military relations is a function of their focus on strategic-level issues. For example, the U.S. is comfortable positing and conducting a host of low-level military contacts in the absence of total strategic compatibility. The Chinese, on the other hand, prefer to have agreement on major strategic principles before engaging in lower-level activities. Consequently, a certain friction is built into the act of crafting military relations between China and the U.S., even under the best conditions.

(Dr. David Finkelstein, (703) 824-2952)

FA-18E/F survivability testing

The FA-18E/F is the Navy's new strike-fighter aircraft, intended to replace the A-6 and the aging fleet of F-14s. In the operational test and evaluation of the FA-18E/F, recently completed at China Lake, fighter aircrews tested the aircraft's ability to perform all strike-fighter missions and survive against surface and air threats. VX-9 asked CNA for analytical help during the OPEVAL to support survivability testing.

We developed a methodology in response to that request. Note that the methodology would not prove one aircraft more survivable than another. Rather, it quanitified what before was an informal process—a group of testers making a subjective and collective judgement from a mix of hard data and qualitative observations. We developed metrics to evaluate survivability and designed flight tests to collect the required data. We also collaborated with survivability experts and fighter aircrews to develop a survey of evaluation items that addressed all aspects of strike-fighter survivability. An expert panel of fighter aircrew then scored these items for the FA-18 E/F relative to the FA-18C, based on our comparative results from the flight test and analysis. Panel members also weighted the individual items based on their perceived level of importance to aircraft survivability as a whole. We then calculated a weighted average from the panel inputs and used the weighted average distribution statistics to give the single answer implied by the survivability requirement.

(Dr. Mike Shepko, (703) 824-2529)

SAM countertactics

Current surface-to-air missile countertactics were designed and developed in the 1960s to counter a specific threat in the Vietnam war. The countertactics are relatively complex; for example, they are tailored to specific threat types and differ based on aircraft altitude. At least twenty years have passed since the effectiveness of the countertactics have been studied in any systematic, analytic fashion. To determine whether the current tactics remain effective today or whether more effective tactics could be developed, the Naval Strike and Air Warfare Center has initiated a zero-based review of SAM countertactics employed in strike-fighter aviation. Its goal is to promulgate the best tactics for reducing the probability of a SAM engagement and surviving those that do occur.

CNA is supporting NSAWC's review with a project that focuses on two aspects of the problem: flight profiles that will reduce the quality of a SAM's radar track of a potential target; and maneuvers that will decrease the effectiveness of missiles that engage aircraft. The goal of the project is to examine the potential effectiveness of the maneuvers themselves, independent of stand-off or self-screening electronic countermeasures support. To address the issue of system performance against candidate maneuvers, we conducted tactical tests at ECR-China Lake to obtain data on system performance from the instrumented threats there; we analyzed that data to assess the relative effectiveness of the maneuvers against the various threats. We developed modeling tools to address the issue of effectiveness of maneuver against missiles in flight. As a result of the analysis, new countertactics proposals have been incorporated into NSAWC's training curriculum.
(Dr. Mike Webb, (703) 824-2533)

CNA analysts honored

Three CNA analysts have been honored recently by the Department of the Navy. On 22 November, the Commanding General of the Marine Corps Warfighting Laboratory presented the Meritorious Civilian Service Award to Mr. Dwight Lyons . Mr. Lyons worked at the lab for the past four years. During that time, he played a decisive role in structuring experiments and subsequent analyses. He was, for example, a primary driver in establishing the program of instrumentation for lab experiments that was vital for automated data collection and reconstruction of experiment events.

For his outstanding performance while serving as CNA's field representative to III Marine Expeditionary Force in Okinawa, Dr. John Wilson received the Meritorious Public Service Award from the Commandant of the Marine Corps. While assigned to III MEF, Dr. Wilson contributed analytically to a variety of operational issues. Also, as the citation notes, "he exhibited exceptional professional competence in planning, coordinating, and guiding all facets of policy development in support of a wide variety of operational missions." Dr. Wilson is currently CNA's representative to MARFORLANT.

The Surgeon General of the Navy presented the Meritorious Public Service Award to Dr. Neil Carey for his outstanding service as consultant to Navy Medicine's Flag Council. The citation notes that "Dr. Carey's superb performance of his duties was instrumental in developing a set of numerical measures that quantify progress towards the goals outlined in Navy Medicine's Strategic Plan." Further, understanding that the initial metrics might be superseded as better data become available, Dr. Carey developed a method for rescaling the measures in the future.

The CNA Quarterly provides summaries of research conducted by the Center for Naval Analyses.
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